

# Equity in accessibility: moving from disparity to insufficiency analyses

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## Introduction

Over the past several decades, the research and practice of transport planning have been going through two slow, but profound, shifts in focus. The first is a shift from mobility to accessibility (Cervero, 2001; Handy, 2020); the second a shift from efficiency and aggregate outcomes to a concern for equity and disaggregate, group-specific, outcomes (Pereira & Karner, 2021; Martens, 2021). Both shifts are far from complete but hold enormous potential to reshape the practice of transport planning as well as policy priorities.

The growing number of studies that map, analyze, and explain accessibility levels across metropolitan areas in the US and elsewhere are evidence of both these shifts. While initially most studies explored general patterns of accessibility, more recent studies analyze disparities in accessibility levels, with a particular concern for disadvantaged groups as defined along lines of income, race, or car ownership, among others (see Section 'Equity analyses of disparities in accessibility').

In this paper, we argue that the shift from efficiency to equity is incomplete if it does not go beyond examining disparities. We present both theoretical arguments and empirical evidence that call into question the suitability of disparity analyses to determine whether accessibility patterns are equitable or not. While disparity analyses have been crucial in triggering the shift from efficiency to equity and can provide valuable input for debates about equity in transport, we argue that such analyses fail to answer the critical equity question whether all people enjoy a level of accessibility that allows full participation in society. Hence, we propose adopting a sufficiency approach to assess the equity of accessibility patterns.

We start our argument with a brief review of disparity analyses in the academic literature and planning practice. We then critically discuss the problems embedded in

these analyses and propose equity analyses employing a sufficiency principle as an alternative. This approach requires answering the difficult question: “What level of accessibility is sufficient?” While the exact answer to this question is not essential for our argument, we will nevertheless discuss this question at some length in the fourth section, resulting in an inevitably value-laden accessibility sufficiency threshold.

In the results section, we employ this example accessibility sufficiency threshold to analyze the situation in 49 of the 50 largest US metropolitan areas. We compare our findings with results of a disparity analysis, showing how the latter may hide rather than reveal the unfair treatment of a substantial share of the population. We end the paper with implications for practice, calling on transport professionals to conduct sufficiency analyses to (1) determine transport inequities in their jurisdictions, and (2) assess impacts of proposed interventions to mitigate these inequities. While sufficiency analyses raise difficult value-laden questions, we argue that progress towards transport equity can only be made if such questions are explicitly addressed in policymaking.

### **Equity analyses of disparities in accessibility**

The accessibility literature has proliferated over the past decades (e.g., Hu, 2015; Levine, 1998; Levine et al., 2012; Yan, 2021). The literature is diverse in terms of research questions, adopted approaches, and employed accessibility measures. This is no surprise, in part because of accessibility’s relation with economic development, real estate values, mode choice, social cohesion and so on, and in part because of the multiple ways in which accessibility can be measured. The literature on the nexus between accessibility and equity reflects this diversity. Studies have analyzed access to a variety of destinations, including employment, health care, education, food stores, and public open spaces (e.g., Bierbaum et al., 2020; Boisjoly et al., 2020; Grengs, 2001). Here, we limit ourselves to studies employing measures of job accessibility to identify differences in accessibility between distinct socio-economic and demographic groups in US cities, as our subsequent empirical analyses employ a comparable accessibility measure and are limited to this national context.

Wachs and Kumagai (1973) were probably the first to systematically and explicitly compare accessibility levels experienced by different socio-economic groups. Focusing on car-based accessibility to employment in the Los Angeles area, they found that lower and higher income groups had better access to their respective job categories than middle income groups. While this early paper did not use the terminology of disparity or equity but that of equality of opportunity, its approach is much in line with more recent disparity studies.

This first pioneering study did not generate many follow-up studies, either in the US or beyond (with some notable exceptions, e.g., Black & Conroy, 1977; Breheny, 1978). Most studies published in the following two-and-a-half decades used accessibility as an explanatory variable, without reporting in much detail about accessibility differentials between socio-economic groups (e.g., Bederman & Adams, 1974; Blumenberg & Ong, 1998; Burns & Golob, 1976; Cervero et al., 1999; Ihlanfeldt, 1993; Ihlanfeldt & Sjoquist,

1990; Ihlanfeldt & Sjoquist, 1991; Levinson, 1998; Mattsson & Weibull, 1981; O'Regan & Quigley, 1998; Sanchez, 1999).

Toward the end of the 1990s, disparities in accessibility became a distinct topic of research, in the US and elsewhere. Inspired by the spatial mismatch hypothesis (Kain, 1968), some studies focused on disadvantaged groups only (e.g., Hess, 2005; Hu, 2015; Kawabata, 2003; Shen, 1998). Most recent studies explored disparities across the entire (adult) population, distinguishing between advantaged and disadvantaged groups based on income, race, car-ownership, residential location, or some of these combined (e.g., Blanchard & Waddell, 2017; Borowski et al., 2018; Gazze, 2018; Grengs, 2010).

Three types of disparity studies can be distinguished. The first limits the analyses to accessibility by a particular transport mode, in line with the pioneering study by Wachs and Kumagai (1973). While some studies analyzed car-based accessibility (e.g., Helling, 1998; Hu, 2015), most focused on transit (e.g., Blanchard & Waddell, 2017; Borowski et al., 2018; Fan et al., 2012; Gazze, 2018). Studies typically found that disadvantaged groups (e.g., low-income groups, carless households, racial minorities) were served better than their advantaged counterparts. This is explained by the residential location of the former groups who tend to live in neighborhoods with better transit service and closer to major employment concentrations. Yet, some studies reached opposing results, such as Blanchard and Waddell (2017), who have found that neighborhoods with an above-average income in the San Francisco Bay Area enjoyed somewhat higher transit accessibility than poorer neighborhoods.

These mode-specific analyses have been criticized for ignoring the large gaps in car availability among socio-economic groups and thus misrepresenting the actual accessibility disparities (e.g., Golub et al., 2013). In an effort to address this, some studies have accounted for car availability among different groups and calculated mode-weighted accessibility levels for each group (e.g., Chen & Akar, 2017; Grengs, 2010, 2012). In one such study, Grengs (2012) assessed accessibility differentials by race and found that, on aggregate, racial minorities enjoyed higher accessibility to employment by virtue of their central location, despite their substantially lower levels of car ownership.

A third type of studies does not focus directly on disparities between groups but analyzes the gaps between car-based and transit-based accessibility at the level of neighborhoods, block groups, or census tracts (Golub & Martens, 2014; Kawabata, 2009; Kawabata & Shen, 2006, 2007; Wang & Chen, 2015). In line with expectations, these studies have found huge disparities in favor of car-based accessibility.

The interest in accessibility disparities in the academic literature has been paralleled by a comparable development in the practice of (regional) transport planning in the US, as evidenced by three studies on the topic (Karner, 2016; Manaugh et al., 2015; Martens & Golub, 2018). These studies showed that metropolitan planning organizations (MPOs) were consistent in their comparison of groups, even if they varied in the definition of advantaged and disadvantaged groups and how accessibility was measured. Typically conducting mode-specific analyses of accessibility, the analyzed MPOs seemed to consider investment plans equitable if analyses showed that the situation of disadvantaged groups

was roughly on par with, or better than, that of more advantaged counterparts, but they rarely explicitly stated their assessment standards. MPOs also tended to conduct a range of analyses, with sometimes opposing results regarding the implications for disadvantaged groups.

### **From disparity to (in)sufficiency**

The insights delivered by the disparity-in-accessibility studies, briefly reviewed above, have been key in shaping the slow but gradual shift from efficiency to equity in transport research and planning. Yet, we argue that these analyses do not go far enough to complete this shift, for both philosophical and methodological reasons. In what follows, we discuss our concerns regarding disparity analyses and subsequently show how the proposed sufficiency approach can address these issues.

First, disparity analyses of accessibility rarely address the fundamental question about the normative principle that should guide equity analyses. Analyses are typically guided by variations of the principle of equality (i.e., simple equality, proportionality, or equalization), but often refrain from using any equity-related language or use such language loosely without specifying or justifying the implicit principle that is being employed (Lewis et al., 2021). Likewise, planning agencies rarely provide a justification for the employed equity principle(s). Martens and Golub (2018, p. 12) even concluded that the analyzed MPOs seemed to use equity standards in a “haphazard” and “opportunistic” way. Possibly, the implicit use of the equality principle may raise few questions because the principle is intuitively appealing and also considered the default principle in social justice literature (Kolm, 1996). Yet, the adoption of a particular principle can have far-reaching implications and sidestepping the issue is at odds with the very purpose of an equity analysis.

Second, disparity analyses are inevitably concerned with a comparison of *groups* distinguished along lines of race, income, car-ownership and so on. For this purpose, disparity analyses must rely on group-wide averages. The implication is that substantial differences *within* groups may be evened out. This may occur in mode-specific analyses, with low accessibility levels for group members living at the metropolitan edge being balanced out by high levels enjoyed by group members in the urban core. It may occur in mode-weighted analyses, as high car-based accessibility for many group members may hide extremely low transit accessibility for others in the same group (cf. Grengs, 2010, 2012). It may even apply to studies comparing accessibility between transport modes, as their focus on modal gaps may lead to a lack of attention for the superior yet low levels of car-based accessibility at the urban edge or relatively good, but still poor, transit accessibility in the urban core.

While this issue is sometimes mentioned (e.g., Hess, 2005; Wachs & Kumagai, 1973) and Grengs (2010, p. 49) explicitly discussed the “ecological fallacy” embedded in disparity studies, most analyses report on the differences between large groups with little attention for possible in-group variation. While assessing equity based on group-wide averages can certainly provide important insights, the approach falls short of addressing the very essence of equity analyses: accounting for each person’s situation. Not only

philosophers of social justice agree that “the ultimate units of concern are (...) persons” (Pogge, 2002, p. 169). Similarly, Title VI of the Civil Rights Act clearly suggests that equity analyses should address persons, not groups.<sup>1</sup>

These two concerns together lead to a third issue: the use of equality as the normative principle guiding equity analyses of accessibility. Once the focus shifts from groups to individuals, as required from a philosophical perspective, the problematic nature of this principle becomes clear. For one, equality in accessibility is an empirical impossibility, as accessibility levels will always vary across space for reasons of geography (Puu, 2005). Disparity analyses can sidestep this by measuring group averages, as equality is a possibility at the aggregate level. Yet, this approach falls apart once the attention is directed to the situation of individuals. In that case, differences in accessibility between people will inevitably be revealed, across both space and socio-economic characteristics, challenging the intuitive reliance on the equality principle. Hence, equity analyses that take all persons seriously have to be guided by a different normative principle.

In light of these issues, we argue that equity analyses should move away from disparity analyses. Instead, equity analyses should (1) account for the situation of each person; and (2) be based on an explicit equity standard.

The selection of an explicit equity standard is obviously a major political challenge. While it should ultimately result from a process of democratic decision-making, that process should be informed by two key considerations. First, it should start from the empirical observation that equality in accessibility is an impossibility. Second, it should be based on an explicit acknowledgement of the fundamental role of accessibility in people’s lives. In technical terms, accessibility is a measure of the number and variety of activities people can reach within a reasonable amount of time, cost and effort (Hansen, 1959). At a more philosophical level, accessibility is a measure of freedom, with freedom understood in a positive rather than a negative way: “freedom to” rather than “freedom from” (Berlin, 1958, p. 43). The literature provides ample evidence of the far-reaching implications of (extremely) low levels of accessibility and the lack of freedom they reflect: unemployment, reduced uptake of key services such as health care and education, and social isolation (e.g., Bierbaum et al., 2020; Blumenberg & Pierce, 2014; Lucas, 2012).

We argue that this latter body of literature points at sufficiency as a suitable standard for equity analyses in accessibility. Such a principle has indeed been endorsed and defended in the more philosophical literature on the topic (Farrington & Farrington, 2005; Kronlid, 2008; Martens, 2017; Pereira et al., 2017; see for a more general defense of sufficiency: Frankfurt, 1987). If carefully set and systematically implemented, such a standard can avoid transport-related social exclusion. In contrast, possible alternatives, such as a maximum difference between the worst-off and the best-off, do not necessarily guarantee adequate accessibility for all. For this reason, we follow the cited literature and propose adopting this principle in equity analyses of accessibility.

### **Setting a sufficiency threshold for accessibility**

The adoption of a sufficiency standard for equity analysis leaves an important question unanswered: What is a sufficient level of accessibility? This is both an empirical and a

normative question. It is empirical, because a sufficiency standard cannot be set without knowledge about the impacts of a low level of accessibility on a person's life. It is normative because empirical analyses will never deliver an unequivocal sufficiency standard. Empirical evidence can only provide input for an explicitly normative process of decision-making; it cannot replace it. The field of transport does not differ here from other policy domains, where agreement on a general equity principle (for instance, clean air for all) may go hand in hand with sometimes strong disagreement on the exact policy standard (e.g., a maximum of 0.15 µg/m<sup>3</sup> or 0.10 µg/m<sup>3</sup> for lead (Pb), using a monthly or yearly average?).

Our approach to set a sufficiency threshold starts from our understanding of accessibility as an, arguably technical, measure of people's freedom to engage in out-of-home activities. In what follows, we will be using a measure of employment accessibility to gain an understanding of this freedom. Since jobs are correlated with multiple opportunities (shops, health care and so on) and tend to be distributed over an urban area (much more than, for instance, hospitals or parks), we consider employment accessibility to be a general, albeit rough, measure of accessibility freedom. In addition, employment accessibility may indirectly contribute to accessibility freedom through its impact on a person's income. Drawing on Martens (2017, Chap. 7), we assume that a higher level of accessibility implies a larger opportunity space and is thus likely to enhance the frequency and quality of out-of-home activity participation, *ceteris paribus*. Since people may compete for opportunities (a job, a place in a school, a spot in a restaurant), we deem a relative measure of accessibility most suitable to obtain an estimate of a person's opportunity space and will thus use a benchmark that is dependent on the average accessibility in a metropolitan area. We underscore that accessibility is ultimately a measure of a person's choice set and that any "estimation of what *could* be chosen is, by its very nature, problematic" (Sen 1990, p. 49 – emphasis added). Hence, we argue that there is no perfect accessibility measure, but only proxy values (Vecchio & Martens, 2021). Our specification of a sufficient level of accessibility is based on these considerations.

This specification of the purpose of accessibility measurement still leaves unaddressed what is a sufficient level of accessibility. While there is an abundance of qualitative and quantitative studies on the possible impacts of low levels of accessibility, few studies have sought to generate systematic information for setting a possible sufficiency threshold. Most relevant literature has focused on the relationship between accessibility and employment. This literature has delivered mixed results, with some studies showing little or no impact (e.g., Blumenberg, 2002; Taylor & Ong, 1995), while others finding a (modest) positive relationship (e.g., Bastiaanssen et al., 2020; Ong & Houston, 2002; Sanchez, 1999). Yet, few of these studies provided straightforward input for the setting of a sufficiency threshold, as they focused on the estimation of the strength of the relationship rather than on the possible existence of a threshold. Moreover, these studies typically only analyzed effects on employment, even though improved job accessibility may enhance participation in other activities as well because of its correlation with accessibility to other opportunities.

To the best of our knowledge, only two studies have delivered pointers for setting a possible sufficiency threshold. The first is by Allen and Farber (2020) for the Toronto area. They used a gravity-based measure of accessibility to employment to analyze the relationship between transit accessibility and overall activity participation, for distinct population groups defined by income and car ownership. For the neighborhoods with the highest levels of transit accessibility, they found that “activity participation among zero-car, low-income, and all households equalizes” (p. 7), suggesting that this highest level of accessibility is certainly adequate. Allen and Farber subsequently represented the relationship between accessibility and activity participation for low-income carless households as an S-curve, with activity participation hardly responding to accessibility increases at very low and very high levels of accessibility but being very sensitive to accessibility increases in the middle range. While these findings do not provide direct input for setting a sufficiency threshold, they do suggest that the threshold should be positioned somewhere in this ‘middle range’ of accessibility.

The second study is by Smart and Klein (2020), who analyzed the relationship between accessibility and poor individuals’ employment and labor earnings. Using the same accessibility data as we employ in what follows, they found that at very high levels of transit accessibility, the impacts on job earnings were comparable to the impact of having access to a car. More precisely, at the 95<sup>th</sup> percentile of transit accessibility in a metropolitan region, the differences in earnings between the poor who had access to a car and those who did not disappeared. Moreover, below the 75<sup>th</sup> percentile, transit accessibility had no impact on earnings. This suggests that any sufficiency threshold below 75% of metro-level peak transit accessibility would have little relevance, at least in terms of earnings from employment.

These two studies represent a valuable, albeit limited, basis for setting a sufficiency threshold. Lacking a robust empirical basis and a politically agreed-upon sufficiency threshold, the setting of a threshold is inevitably partly arbitrary. We base our threshold on three considerations. First, the sufficiency threshold should be context-sensitive, given the large differences in absolute accessibility levels between metropolitan regions. Second, it should be based on a benchmark which almost certainly reflects a sufficient level of accessibility. Given the dominance of the private car in US regions, we argue that population-weighted *average* car-based accessibility is highly likely to represent a sufficient level of accessibility, i.e., to provide a basis for adequate participation in activities. Third, the sufficiency threshold should be a reasonable proportion of this benchmark. A very high sufficiency threshold might position the standard above the middle range identified by Allen and Farber (2020). A very low sufficiency threshold would risk setting a standard justifying existing patterns of accessibility insufficiency rather than setting a standard worth striving for.

Given these complexities and considerations, we conducted two types of analyses. When analyzing accessibility inequities across all 49 metropolitan regions jointly, we employed a range of sufficiency thresholds. For each region, these thresholds were based on average regional car-based accessibility and range from 1% to 50% of that average. To illustrate, the 50% threshold means that transit is deemed sufficient if it provides

accessibility to at least half of all jobs that are accessible by car on average in that region. For the region-specific analyses we primarily used the 10% sufficiency threshold. This threshold is in line with the finding of Smart and Klein (2020): the 95th percentile of block group transit accessibility corresponds, on average, to ~12% of average metropolitan car-based accessibility.

### **Methods and data**

We analyzed accessibility patterns in 49 of the 50 largest US metropolitan areas. We conducted disparity analyses, insufficiency analyses and disparities-in-insufficiency analyses, which are further specified below.

In a complete equity analysis, the accessibility enjoyed by all residents in a metropolitan area would be assessed. However, we only had fine-grained data on transit accessibility. Hence, our analyses should focus on the population segment that could benefit from transit. Given that car-based accessibility is higher than transit accessibility virtually everywhere in the US (see above), transit provides no or limited accessibility benefits to people with access to a car. Hence, our analyses should focus on the population with no or limited access to a car. This population segment could be identified based on car-ownership, income level, or a combination of both. In our analyses, we relied on income alone and limited the analyses to the population with incomes below the official US poverty line. We did not take into account car-ownership for two reasons. First, some persons may be car-free out of choice while having adequate income to acquire (access to) a car and thus to car-based accessibility if necessary (Johnson et al., 2010). Second, using car ownership as an indicator would ignore households for whom car ownership and use represent a severe financial burden and whom could have thus benefited from improved transit services (Currie & Delbosc, 2013; Mattioli, 2017). While currently even the poor use transit for only a modest share of their trips in the US (Giuliano, 2005), there is abundant evidence showing the precarious nature of car ownership among low-income households (Blumenberg & Agrawal, 2014; Klein, 2020; Lowe, 2014). Hence, we argue that low-income adults could benefit substantially from transit *if it was of sufficient quality* (Kawabata, 2003; Yousefzadeh Barri et al., 2021).

In our analysis, we thus focused on the population below the official income poverty line. Hence, our disparity and insufficiency analyses were partial; they did not capture disparities in car-based accessibility, nor whether some share of higher income groups faced insufficient accessibility in spite of having access to a car. While disparities in car-based accessibility have been the subject of a range of studies (see above), future research should certainly measure the extent of insufficient accessibility among people with incomes above the poverty line who can presumably rely on cars.

### ***Disparity analysis***

The purpose of the disparity analyses was to identify differences in transit accessibility between population groups. We used the index proposed by Borowski et al. (2018). They calculated for each sub-group “the ratio of the person-weighted average accessibility provided to the group of interest compared to the person-weighted average accessibility provided to the general population” in a metropolitan region (p. 6). A ratio above “1”

indicates that a group enjoy on average higher transit accessibility than the entire population in that region. We compared groups based on income and based income and race jointly. We distinguished between four racial groups: Whites, Blacks, Hispanics and Other.<sup>2</sup>

### ***Sufficiency analysis***

In order to assess the level of insufficiency in accessibility in the 49 metropolitan areas, we adopted the Accessibility Fairness Index proposed by Martens (2017) and renamed it the Accessibility Sufficiency Index (ASI) to better reflect the purpose of our analyses. The ASI merges two dimensions of insufficient accessibility:

- The number of people experiencing an accessibility level below an agreed-upon sufficiency threshold. The more people below this threshold, the higher the ASI score.
- The 'accessibility shortfall' experienced by people positioned below the sufficiency threshold, i.e., the gap between their accessibility level and the sufficiency threshold for accessibility.<sup>3</sup> The lower the level of accessibility experienced by people below the sufficiency threshold, the higher the ASI score.

The ASI score can vary between 0 and 1, with higher values indicating more severe levels of accessibility insufficiency. This overall score makes it possible to compare regions and analyze changes over time. Moreover, the index is totally decomposable and subgroup consistent. This means that the contribution of each population group to overall accessibility insufficiency in a region can be expressed as a percentage, with the contributions of all subgroups together adding up to exactly 100%. We refer to the Technical Appendix for more detail.

### ***Data***

The disparity and sufficiency analyses require demographic data, and data on transit accessibility and average car accessibility. Demographic data were obtained at the block-group level from the American Community Survey 2011-2015 5-year estimates (United States Census Bureau, 2016). We combined available data in such a way as to obtain reasonable estimates of the share of poor in each racial group at the block-group level.

Accessibility data were obtained from the Accessibility Observatory at the University of Minnesota (Owen et al., 2017). This source provides transit accessibility data at the census block level for 49 of the 50 largest US Metropolitan Statistical Areas (data are not available for Memphis). We used transit accessibility estimates for a 30-minute travel time threshold, the only data that the Accessibility Observatory makes publicly available. Accessibility data were aggregated to the block-group level by calculating the weighted average with 2010 population at the census block level to match the other demographic data (United States Census Bureau, 2018). The Accessibility Observatory calculates transit travel times using all components of a transit journey, including access and egress walking segments and transfers, and account for minute-by-minute variations in service frequency for the 7:00 – 9:00 a.m. period (Owen et al., 2017). Average car-based accessibility in peak hours, also for a 30-minute travel time threshold, was used as the basis for calculating the

accessibility sufficiency thresholds. All analyses were performed using R and Python algorithms and conducted in the ESRI ArcMap environment (version 10.8).

### ***Limitations***

Our analyses have several limitations. Like any accessibility index, the measure we have adopted is inevitably a rough estimate of a person's experienced accessibility (Vecchio & Martens, 2021). First, our measure only includes job accessibility and thus provides limited information on accessibility to other destinations like shops or health care. Second, it does not account for people's qualifications and job types. Third, the accessibility calculations are based on home-to-work trip times and thus do not account for the challenges (and possible benefits) of trip chaining (Blumenberg, 2004). Fourth, we employed a cumulative accessibility measure, which ascribes equal value to nearby and distant jobs and does not account for job competition. We captured competition to some extent by setting region-specific sufficiency thresholds, thereby indirectly yet imperfectly capturing the worker-job balance. These limitations may affect the empirical results and thus warrant further exploration. Yet, while we acknowledge that different specifications of the accessibility measure would affect the results, we do not expect them to generate distinctly different patterns of disparities or insufficiency. This claim is confirmed by our analyses of accessibility insufficiency for distinctly different sufficiency thresholds, all of which showed substantial insufficiency in all analyzed regions (Table 2).

## **Results**

### ***Disparity analysis***

The disparity analyses showed that in virtually all analyzed metropolitan areas disadvantaged groups received a higher level of transit accessibility than their advantaged counterparts. Taking all metropolitan areas together, the poor clearly enjoyed better transit accessibility than the non-poor, as reflected in median ratios of 1.60 and 0.90 respectively (Table 1, column a). Likewise, across all metropolitan areas, all four low-income racial groups experienced better transit accessibility than the average person in a region (Table 1, column b1), with the highest transit accessibility experienced by the poor Black population (median ratio of 2.08). Only in two regions did the poor White population receive a slightly lower level of transit accessibility than the average person in the region: Riverside and Hartford (ratios of 0.98 and 0.99, respectively).

When comparing the four poor racial groups with one another, it proved that Black and Hispanic poor were served better than White poor (Table 1, column 2b). Measured across all metropolitan areas, Black poor enjoyed, on average, the highest level of transit accessibility (median ratio of 1.27), followed by Others (1.15), Hispanics (0.94) and Whites (0.82). This overall result hides that Blacks and Hispanics experienced worse transit accessibility than the average poor person in respectively 7 and 26 regions, and worse than the average poor White person in respectively 5 and 15 regions. Still, poor Whites were the most poorly served group in 33 metropolitan areas, with a median ratio as low as 0.75 in these regions.

Despite some variation, our results are thus largely in line with mode-specific disparity analyses found in the literature. They show that, in most cases, disadvantaged groups experience a higher level of transit accessibility than more advantaged population groups. Such mode-specific analyses, which are increasingly conducted in practice (Manaugh et al., 2015), often lead to comforting conclusions in equity assessments performed as part of regional transport plans (see Martens & Golub, 2021, p. 434-435).

**Table 1.** Disparity analysis: Relative level of transit accessibility for (a) groups distinguished by income; and (b) groups distinguished by income and race. Ratios below 1 are marked in gray and indicate that a group experiences a lower level of accessibility than the average for the benchmark population (i.e., the total population for (a) and (b1), and the total poor population for (b2)).

-- insert Table 1 about here --

### ***Sufficiency analysis***

In contrast to the disparity analyses, our sufficiency analyses revealed a clear inequitable pattern across all 49 metropolitan areas jointly, irrespective of the sufficiency threshold employed (Table 2). Even for the lowest 1% threshold, when transit is considered sufficient if it provides access to only 1% of jobs accessible by car for the average metropolitan resident, over 10 million poor people faced a sub-standard level of accessibility. When the 10%-threshold was used, the population affected nearly doubled to 19 million, representing as much as 90% of the poor population. The share of the poor population affected by insufficient accessibility continued to increase slowly beyond this 10%-threshold, ultimately reaching over 99% of the poor population for the 50%-threshold.

**Table 2.** Sufficiency analysis: Number of people and share of population affected by insufficient accessibility across all 49 metropolitan areas.

-- insert Table 2 about here --

When we employed the 10%-sufficiency threshold, a large portion of the poor population in each region experienced insufficient accessibility (Figure 1). The share varied between 70% (Philadelphia) and 100% (Las Vegas, San Jose, and Riverside), with the underserved population ranging from ~97,000 (Hartford, 76% of poor population) to 1.9 million (Los Angeles, 93%) and 2.1 million (New York, 82%). Even when the lowest 1% threshold was employed, a substantial share of the poor population in each region experienced insufficient accessibility, ranging from 19% in Milwaukee up to 81% in Atlanta (Figure 1). Overall, these numbers underscore the vast inequities that are revealed when a sufficiency approach is adopted.

**Figure 1.** Sufficiency analysis: Share of the poor population in each region facing insufficient accessibility when employing the 1%- and 10%-sufficiency threshold. The number behind each bar represents the regional Accessibility Sufficiency Index (ASI) score for the 10%-sufficiency threshold; the higher the number the more inequitable the region.

-- insert Figure 1 about here --

### ***Disparities in insufficient accessibility***

We have enriched our insufficiency analysis with two ‘disparity-in-insufficiency’ analyses. The aim here was *not* to identify whether inequities in accessibility exist, as the sufficiency analyses have already revealed these inequities. The purpose, instead, was twofold: first, to determine whether observed insufficiencies have a racial dimension, and second, to illustrate the problematic nature of disparity analyses, even if conducted within the framework of a sufficiency approach.

When comparing the share of poor Whites, Blacks, Hispanics and Others below the accessibility sufficiency threshold with the share of each group in the total poor population, we found that most ratios are close to one. This implies that roughly the same share of each racial group faces insufficient accessibility (Table 3a). The only clear exception occurred for the lowest 1%-threshold, with a disproportionately high share of poor Whites facing insufficient accessibility, a result of the relatively peripheral residential location of poor Whites.

The result of the analysis was entirely different when both the number of people below the sufficiency threshold and their subpar accessibility levels were taken into account. For this analysis, we calculated the ratio of each group’s ASI contribution and that group’s share in the total poor population. We refer to this ratio as the ASI contribution ratio, with a value above 1 signaling that a group contributes *more* to accessibility insufficiency than its share in the population.

The results showed that Whites contributed consistently more to accessibility insufficiency than their share in the poor population, a finding that holds across all sufficiency thresholds (Table 3b). The higher the sufficiency threshold, the smaller the differences between racial groups. Yet, even for the highest sufficiency threshold, Whites still contributed more and Hispanics still clearly less to accessibility insufficiency than their respective shares in the poor population. This latter analysis thus suggests that poor Blacks and Hispanics are *not* disadvantaged in comparison to poor Whites, when analyzed across all 49 metropolitan areas.

**Table 3.** Disparity-in-insufficiency analysis for the 10%-sufficiency threshold: (a) The relative share of each racial group in the total poor population experiencing insufficient accessibility; and (b) the relative contribution of each racial group to overall accessibility insufficiency (ASI contribution ratios). Ratio values above 1 imply that a group carries more than its fair share and so is relatively disadvantaged.

-- insert Table 3 about here --

These findings still largely hold when analyzing disparity-in-insufficiency at the metropolitan level, although the situation is less clear-cut (Table 4). Using the 10%-sufficiency threshold, Whites still contributed more than their fair share to accessibility insufficiency in all regions except for Austin and San Jose, whereas Hispanics contributed more than their fair share in 18 regions, and Blacks in only three regions (Austin, Los Angeles, and Miami). The relative advantage of Hispanics and especially Blacks was even more clear-cut for the 1%-sufficiency threshold, but also held for higher thresholds, even though it gradually decreased as the threshold was raised (Appendix B1).

While these findings are perhaps encouraging, the results of our disparity-in-insufficiency analysis may actually divert attention from substantial inequities, much like regular disparity analyses. For instance, the ASI ratios in Philadelphia clearly direct the attention to Whites rather than Blacks, with a ratio of 1.45 versus 0.64. Yet, the low ratio for Blacks hides that over 150,000 poor Black residents experience insufficient accessibility (Appendix A1). In San Antonio Hispanics have the lowest ASI ratio (0.95 versus 1.13 for Whites), yet about two-thirds of poor Hispanics in the region face insufficient accessibility, making them the largest group in absolute numbers (~ 200,000 persons). In contrast, the disparity-in-insufficiency analysis for Austin directs the attention to Blacks and Hispanics, with ASI ratios of 1.04 and 1.05 respectively. Whites, in comparison, contribute slightly less than their fair share to regional accessibility insufficiency. Yet, the number of affected Whites not only outnumbers Blacks, but the average poor White can also reach fewer jobs by transit than the average poor person of any other racial group (Appendix A1 and B2).

These examples underscore once again the risk embodied in a disparity analysis. Even if conducted *within* the framework of a sufficiency analysis, a disparity analysis may divert the attention away from a group that is *relatively* better positioned in comparison to other groups, yet suffers from severe inequities in *absolute* terms. From a sufficiency perspective, each individual experiencing insufficient accessibility constitutes an inequity, irrespective of whether they belong to a group with a relative 'advantage' over other groups or not.

**Table 4.** Disparity-in-insufficiency analysis: ASI contribution ratios showing the relative share of accessibility insufficiency carried by each racial group in relation to a benchmark population, for the 10%-sufficiency threshold. Ratios above 1 (highlighted in bold) indicate that a group carries more than its fair share of accessibility insufficiency.

-- insert Table 4 about here --

### Discussion and conclusion

In this paper, we have reflected on the suitability of disparity analyses for assessing equity in accessibility. While such analyses provide valuable input for debates about equity in transport, we argue that they are problematic for at least two reasons. First, they do not

allow answering the critical question whether all people enjoy a level of accessibility that enables full participation in society. Second, they are based on aggregated group averages that hide possibly large in-group variance. For both reasons, disparity analyses may come to comforting conclusions, even though a substantial share of the population experiences extremely low levels of accessibility.

Our empirical analyses confirm the problematic nature of disparity analyses. While our sufficiency analyses reveal large inequities in accessibility, the disparity analyses lead to the encouraging conclusion that nearly all disadvantaged groups enjoy *higher* levels of transit accessibility than their more advantaged counterparts. The latter suggests that accessibility patterns and the underlying transit services are distributed in an equitable way in US metropolitan areas, thus soothing the increasing concerns about inequities along lines of income and race. Such outcomes may have far-reaching policy implications. At best, they may assist in maintaining the status quo, as a favorable outcome of an analysis may be interpreted as a positive assessment of existing policy priorities. At worst, the results may shift the balance away from transit services for the poor towards investments for more advantaged groups, based on the argument that disadvantaged groups already receive more than their fair share of service. If disparity analyses are used for such lines of argumentation, they are likely to do more harm than good.

We argue that academics and transport planning agencies serious about equity in the domain of transport should avoid this ecological fallacy whereby characteristics of individuals are mistakenly inferred from aggregate data (Grenng, 2010). They will have to move beyond seemingly neutral disparity analyses and instead adopt an explicit equity standard that accounts for the situation of all people, even if this may lead to uncomfortable findings. Such analyses, based on an explicit and agreed-upon principle, can assist professionals to systematically identify transport inequities in their jurisdictions, thereby providing key input for developing regional transport plans. In a less ambitious application, they may be used to assess and prioritize already proposed interventions based on their contribution to a reduction in observed accessibility insufficiencies.

Disparity analyses can still play a role within this framework, provided their results are interpreted with care. They are particularly relevant for exploring potential *causes* for subpar accessibility and potential biases in transport policies. If such analyses show that one group carries systematically more accessibility insufficiency than others, this may trigger further analyses to determine whether observed disparities are shaped by possible biases in transport policies, in the housing market, or by other factors. Sufficiency and disparity analyses can thus be each other's complement, as long as the ecological fallacy is avoided.

The confronting results from the sufficiency analyses may provoke more guarded responses: critical questions about the adopted accessibility measure and about our equity standard. Clearly, more sophisticated and fine-grained accessibility measures accounting for job types, shift work, job competition, or a broader set of destinations, might be employed. While we would expect comparable inequitable results, such additional analyses are certainly warranted in light of our alarming findings. Critics may also argue that the 10% sufficiency threshold is either too high or too low, completely arbitrary, or

simply an inappropriate principle for transport. Clearly, the adopted threshold will affect the results. But the fact that a threshold will always be value-laden to some extent should not deter scholars and policymakers from carrying out assessments based on a benchmark. Thresholds, benchmarks, and norms are common in many policy fields and are also frequently relied upon when analyzing transport (and housing) affordability (e.g., Fan & Huang, 2011; Litman, 2013). If transport professionals consider accessibility a key performance indicator (Levine et al., 2012), as they arguably should, it will be necessary to also adopt an explicit principle and related accessibility *benchmark* to move towards equity.

## Notes

<sup>1</sup>Title VI reads: “No *person* in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance” (Federal Transit Administration of the United States, 2012; emphasis added).

<sup>2</sup>‘Other’ includes all races and ethnicities not included in the first three categories.

<sup>3</sup>The accessibility shortfall is represented by  $(z - y_i)$  in the equations in the Technical Appendix.

## References

- Aivinhenyo, I., & Zuidgeest, M. (2019). Transport equity in low-income societies: Affordability impact on destination accessibility measures. In Lucas, K., Martens, K., Di Ciommo, F., and Dupont-Kieffer, A., editors, *Measuring Transport Equity* (pp. 111–128). Elsevier.
- Allen, J., & Farber, S. (2020). Planning transport for social inclusion: An accessibility-activity participation approach. *Transportation Research Part D-transport and Environment*, 78, 102–212.
- Bastiaanssen, J., Johnson, D., & Lucas, K. (2020). Does transport help people to gain employment? A systematic review and meta-analysis of the empirical evidence. *Transport Reviews*, 40(5), 607–628.
- Bederman, S. H., & Adams, J. S. (1974). Job accessibility and underemployment. *Annals of the Association of American Geographers*, 64(3), 378–386.
- Berlin, I. (2016, original 1958). Two Concepts of Liberty. In Miller, D. (Ed.). *The Liberty Reader* (pp. 33–57). Routledge.
- Bierbaum, A. H., Karner, A., & Barajas, J. M. (2020). Toward mobility justice: Linking transportation and education equity in the context of school choice. *Journal of the American Planning Association*, Online, 16 Sep 2020, 197–210.
- Black, J., & Conroy, M. (1977). Accessibility measures and the social evaluation of urban structure. *Environment and Planning A: Economy and Space*, 9(9), 1013–1031.
- Blanchard, S. D., & Waddell, P. (2017). Assessment of regional transit accessibility in the San Francisco Bay area of California with UrbanAccess. *Transportation Research Record*, 2654(1), 45–54.
- Blumenberg, E. (2002). On the way to work: Welfare participants and barriers to employment. *Economic Development Quarterly*, 16(4), 314–325.
- Blumenberg, E. A. (2004). Engendering effective planning: spatial mismatch, low-income women, and transportation policy. *Journal of the American Planning Association*, 70(3), 269–281.
- Blumenberg, E., & Agrawal, A. W. (2014). Getting around when you're just getting by: Transportation survival strategies of the poor. *Journal of Poverty*, 18(4), 355–378.
- Blumenberg, E., & Ong, P. (1998). Job accessibility and welfare usage: Evidence from Los Angeles. *Journal of Policy Analysis and Management*, 17(4), 639–657.
- Blumenberg, E., & Pierce, G. (2014). A driving factor in mobility? Transportation's role in connecting subsidized housing and employment outcomes in the Moving To Opportunity (MTO) program. *Journal of the American Planning Association*, 80(1), 52–66.
- Boisjoly, G., Deboosere, R., Wasfi, R., Orpana, H., Manaugh, K., Buliung, R., & El-Geneidy, A. (2020). Measuring accessibility to hospitals by public transport: An assessment of eight Canadian metropolitan regions. *Journal of Transport & Health*, 18, 100916.
- Borowski, E., Ermagun, A., & Levinson, D. (2018). Disparity of access: Variations in transit service by race, ethnicity, income, and auto availability. *Pre-print*.

- Breheny, M. J. (1978). The measurement of spatial opportunity in strategic planning. *Regional Studies*, 12(4), 463–479.
- Burns, L. D., & Golob, T. F. (1976). The role of accessibility in basic transportation choice behavior. *Transportation*, 5(2), 175–198.
- Brussel, M., Zuidgeest, M., van den Bosch, F., Munshi, T., & van Maarseveen, M. (2019). Can the urban poor reach their jobs? Evaluating equity effects of relocation and public transport projects in Ahmedabad, India. In Lucas, K., Martens, K., Di Ciommo, F., & Dupont-Kieffer, A., editors, *Measuring Transport Equity* (pp. 85–109). Elsevier.
- Cebollada, A. (2009). Mobility and labour market exclusion in the Barcelona metropolitan region. *Journal of Transport Geography*, 17(3), 226–233.
- Cervero, R. (2001). Transportation planning. In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 15873–15878). Oxford, Pergamon.
- Cervero, R., Rood, T., & Appleyard, B. (1999). Tracking accessibility: Employment and housing opportunities in the San Francisco Bay area. *Environment and Planning A: Economy and Space*, 31(7), 1259–1278.
- Chen, N. & Akar, G. (2017). How do socio-demographics and built environment affect individual accessibility based on activity space? Evidence from greater Cleveland, Ohio. *Journal of Transport and Land Use*, 10(1), 477–503.
- Currie, G., & Delbosc, A. R. (2013). Exploring trends in forced car ownership in Melbourne. In O’Keeffe, B., editor, *Australasian Transport Research Forum 2013 Proceedings* (pp. 1–9). Australian National Audit Office.
- Delafontaine, M., Neutens, T., Schwanen, T., & Van de Weghe, N. (2011). The impact of opening hours on the equity of individual space-time accessibility. *Computers Environment and Urban Systems*, 35(4), 276–288.
- Delmelle, E. C., & Casas, I. (2012). Evaluating the spatial equity of bus rapid transit-based accessibility patterns in a developing country: The case of Cali, Colombia. *Transport Policy*, 20, 36–46.
- Fan, Y., Guthrie, A., & Levinson, D. (2012). Impact of light-rail implementation on labor market accessibility: A transportation equity perspective. *Journal of Transport and Land Use*, 5(3), 28–39.
- Fan, Y., & Huang, A. (2011). *How affordable is transportation? A context-sensitive framework*. Center for Transportation Studies, University of Minnesota.
- Farrington, J. & Farrington, C. (2005). Rural accessibility, social inclusion and social justice: towards conceptualisation. *Journal of Transport Geography*, 13(1), 1–12.
- Frankfurt, H. (1987). Equality as a moral ideal. *Ethics*, 98(1), 21–43.
- Gazze, L. (2018). Inequality in job accessibility via transit in US cities. In *Divided Cities* (pp. 111-133). OECD.
- Giuliano, G. (2005). Low income, public transit, and mobility. *Transportation Research Record*, 1927(1), 63–70.

- Golub, A., Marcantonio, R. A., & Sanchez, T. W. (2013). Race, space, and struggles for mobility: Transportation impacts on African Americans in Oakland and the East Bay. *Urban Geography*, 34(5), 699–728.
- Golub, A., & Martens, K. (2014). Using principles of justice to assess the modal equity of regional transportation plans. *Journal of Transport Geography*, 41, 10–20.
- Grengs, J. (2001). Does public transit counteract the segregation of carless households? Measuring spatial patterns of accessibility. *Transportation Research Record*, 1753(1), 3–10.
- Grengs, J. (2010). Job accessibility and the modal mismatch in Detroit. *Journal of Transport Geography*, 18(1), 42–54.
- Grengs, J. (2012). Equity and the social distribution of job accessibility in Detroit. *Environment and Planning B: Planning and Design*, 39(5), 785–800.
- Handy, S. (2020). Is accessibility an idea whose time has finally come? *Transportation Research Part D: Transport and Environment*, 83, 102319.
- Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners*, 25(2), 73–76.
- Helling, A. (1998). Changing intra-metropolitan accessibility in the US: Evidence from Atlanta. *Progress in Planning*, 49(2), 55–107.
- Hess, D. B. (2005). Access to employment for adults in poverty in the Buffalo-Niagara region. *Urban Studies*, 42(7), 1177–1200.
- Hu, L. (2015). Job accessibility of the poor in Los Angeles. *Journal of the American Planning Association*, 81(1), 30–45.
- Ihlanfeldt, K. R. (1993). Intra-urban job accessibility and Hispanic youth employment rates. *Journal of Urban Economics*, 33(2), 254–271.
- Ihlanfeldt, K. R., & Sjoquist, D. L. (1990). Job accessibility and racial differences in youth employment rates. *The American Economic Review*, 80(1), 267–276.
- Ihlanfeldt, K. R., & Sjoquist, D. L. (1991). The effect of job access on black and white youth employment: A cross-sectional analysis. *Urban Studies*, 28(2), 255–265.
- Johnson, V., Currie, G., & Stanley, J. (2010). Measures of disadvantage: Is car ownership a good indicator? *Social Indicators Research*, 97(3), 439–450.
- Kain, J. F. (1968). Housing segregation, negro employment, and metropolitan decentralization. *The Quarterly Journal of Economics*, 82(2), 175–197.
- Karner, A. (2016). Planning for transportation equity in small regions: Towards meaningful performance assessment. *Transport Policy*, 52, 46–54.
- Kawabata, M. (2003). Job access and employment among low-skilled autoless workers in us metropolitan areas. *Environment and Planning A: Economy and Space*, 35(9), 1651–1668.
- Kawabata, M. (2009). Spatiotemporal dimensions of modal accessibility disparity in Boston and San Francisco. *Environment and Planning A: Economy and Space*, 41(1), 183–198.

- Kawabata, M., & Shen, Q. (2006). Job accessibility as an indicator of auto-oriented urban structure: A comparison of Boston and Los Angeles with Tokyo. *Environment and Planning B: Planning and Design*, 33(1), 115–130.
- Kawabata, M., & Shen, Q. (2007). Commuting inequality between cars and public transit: The case of the San Francisco Bay area, 1990-2000. *Urban Studies*, 44(9), 1759–1780.
- Kelobonye, K., McCarney, G., Xia, J. C., Swapan, M. S. H., Mao, F., & Zhou, H. (2019). Relative accessibility analysis for key land uses: A spatial equity perspective. *Journal of Transport Geography*, 75, 82–93.
- Klein, N. J. (2020). Subsidizing car ownership for low-income individuals and households. *Journal of Planning Education and Research*, Online, 9 Sep 2020, 1–13.
- Kolm, S. C. (1996). *Modern theories of justice*. Cambridge, Massachusetts, The MIT Press.
- Kronlid, D. (2008). Mobility as capability. In *Gendered mobilities*. Aldershot: Ashgate.
- Levine, J. (1998). Rethinking accessibility and jobs-housing balance. *Journal of the American Planning Association*, 64(2), 133–149.
- Levine, J., Grengs, J., Shen, Q., & Shen, Q. (2012). Does accessibility require density or speed? *Journal of the American Planning Association*, 78(2), 157–172.
- Levinson, D. M. (1998). Accessibility and the journey to work. *Journal of Transport Geography*, 6(1), 11–21.
- Lewis, E. O., MacKenzie, C., D., & Kaminsky, J. (2021). Exploring equity: How equity norms have been applied implicitly and explicitly in transportation research and practice. *Transportation Research Interdisciplinary Perspectives*, 9, 100332.
- Linard, C., Gilbert, M., Snow, R. W., Noor, A. M., & Tatem, A. J. (2012). Population distribution, settlement patterns and accessibility across Africa in 2010. *PLOS ONE*, 7(2), 1–8.
- Litman, T. (2013). *Transportation affordability: evaluation and improvement strategies*. Technical report, Victoria Transport Policy Institute.
- Lowe, K. (2014). Accessibility for low-income workers in New Orleans, Louisiana, after Hurricane Katrina. *Transportation Research Record*, 2452(1), 46–52.
- Manaugh, K., Badami, M. G., & El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport Policy*, 37, 167–176.
- Martens, K. (2017). *Transport justice: Designing fair transportation systems*. Routledge.
- Martens, K. (2021). Equity considerations in transportation planning. In R. Vickerman (Ed.), *Encyclopedia of Transportation* (vol. 6, pp. 154–160). United Kingdom, Elsevier.
- Martens, K., & Golub, A. (2021). A fair distribution of accessibility: Interpreting civil rights regulations for regional transportation plans. *Journal of Planning Education and Research*, 41(4), 425–444.
- Mattioli, G. (2017). ‘Forced car ownership’ in the UK and Germany: Socio-spatial patterns and potential economic stress impacts. *Social Inclusion*, 5(4), 147–160.

- Mattsson, L.-G., & Weibull, J. W. (1981). Competition and accessibility on a regional labour market. *Regional Science and Urban Economics*, 11(4), 471–497.
- Ong, P. M., & Houston, D. (2002). Transit, employment and women on welfare. *Urban Geography*, 23(4), 344–364.
- O'Regan, K. M., & Quigley, J. M. (1998). Where youth live: Economic effects of urban space on employment prospects. *Urban Studies*, 35(7), 1187–1205.
- Oviedo Hernandez, D., & Titheridge, H. (2016). Mobilities of the periphery: Informality, access and social exclusion in the urban fringe in Colombia. *Journal of Transport Geography*, 55, 152–164.
- Owen, A., Levinson, D. M., & Murphy, B. (2017). *Access across America: Transit 2015*. Technical report, Data Repository for the University of Minnesota.
- Pereira, R. H., & A. Karner (2021). Transportation equity. In R. Vickerman (Ed.), *International Encyclopedia of Transportation* (2021). United Kingdom, Elsevier.
- Pereira, R. H. M., Schwanen, T., & Banister, D. (2017). Distributive justice and equity in transportation. *Transport Reviews*, 37(2), 170–191.
- Pogge, T. W. (2002). *World Poverty and Human Rights: Cosmopolitan Responsibilities and Reforms*. Cambridge: Polity Press.
- Pritchard, J., Bogado Tomasiello, D., Giannotti, M., & Geurs, K. (2019). Potential impacts of bike-and-ride on job accessibility and spatial equity in Sao Paulo, Brazil. *Transportation research. Part A: Policy and practice*, 121, 386–400.
- Puu, T. (2005). On the genesis of hexagonal shapes. *Networks and Spatial Economics*, 5(1), 5– 20.
- Sanchez, T. W. (1999). The connection between public transit and employment. *Journal of the American Planning Association*, 65(3), 284–296.
- Shen, Q. (1998). Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. *Environment and Planning B: Planning and Design*, 25(3), 345– 365.
- Smart, M. J., & Klein, N. J. (2020). Disentangling the role of cars and transit in employment and labor earnings. *Transportation*, 47(3), 1275–1309.
- Taylor, B. D., & Ong, P. M. (1995). Spatial mismatch or automobile mismatch? An examination of race, residence and commuting in US metropolitan areas. *Urban Studies*, 32(9), 1453–1473.
- United States Census Bureau (2016). *2011-2015 American Community Survey 5-year Estimates*. Retrieved: 29 July 2020, from <https://data2.nhgis.org/main>.
- United States Census Bureau (2018). *Metropolitan and Micropolitan*. Retrieved: 18 July 2019, from <https://perma.cc/L2EN-UU64>.
- Vecchio, G., & Martens, K. (2021). Accessibility and the Capabilities Approach: A review of the literature and proposal for conceptual advancements. *Transport Reviews*, 41(6), 833–854.

- Wachs, M., & Kumagai, T. (1973). Physical accessibility as a social indicator. *Socio-Economic Planning Sciences*, 7(5), 437–456.
- Wang, C. H., & Chen, N. (2015). A GIS-based spatial statistical approach to modeling job accessibility by transportation mode: Case study of Columbus, Ohio. *Journal of Transport Geography*, 45, 1–11.
- Yan, X. (2021). Toward accessibility-based planning: Addressing the myth of travel cost savings. *Journal of the American Planning Association*, Online, 3 Feb 2021, 409–423.
- Yousefzadeh Barri, E., Farber, S., Kramer, A., Jahanshahi, H., Allen, J., & Beyazit, E. (2021). Can transit investments in low-income neighbourhoods increase transit use? Exploring the nexus of income, car-ownership, and transit accessibility in Toronto. *Transportation Research Part D: Transport and Environment*, 95, 102849.

**Table 1.** Disparity analysis: Relative level of transit accessibility for (a) groups distinguished by income; and (b) groups distinguished by income and race. Ratios below 1 are marked in bold font and indicate that a group experiences a lower level of accessibility than the average for the benchmark population (i.e., the total population for (a) and (b1), and the total poor population for (b2)).

Metropolitan Area	(a) By Income		(b) By Income and Race							
	Poor	Non-Poor	(1) Relative to Total Population				(2) Relative to Poor Population			
			White	Black	Hispanic	Other	White	Black	Hispanic	Other
Atlanta	1.57	<b>0.91</b>	1.38	1.71	1.16	2.46	<b>0.88</b>	1.09	<b>0.74</b>	1.57
Austin	2.42	<b>0.78</b>	2.93	1.96	1.60	4.7	1.21	<b>0.81</b>	<b>0.66</b>	1.94
Baltimore	2.18	<b>0.85</b>	1.24	3.13	1.82	1.76	<b>0.57</b>	1.43	<b>0.83</b>	<b>0.81</b>
Birmingham	1.86	<b>0.85</b>	1.13	2.7	1.54	2.66	<b>0.61</b>	1.45	<b>0.83</b>	1.43
Boston	2.01	<b>0.88</b>	1.76	2.08	2.08	2.97	<b>0.87</b>	1.04	1.04	1.48
Buffalo	1.76	<b>0.88</b>	1.23	2.48	2.95	2.12	<b>0.7</b>	1.41	1.68	1.2
Charlotte	1.45	<b>0.93</b>	1.09	2.03	1.17	1.63	<b>0.75</b>	1.40	<b>0.8</b>	1.12
Chicago	1.34	<b>0.95</b>	1.4	1.28	1.02	2.47	1.05	<b>0.96</b>	<b>0.76</b>	1.85
Cincinnati	2.23	<b>0.81</b>	1.65	3.78	2.06	3.02	<b>0.74</b>	1.69	<b>0.92</b>	1.35
Cleveland	2.2	<b>0.8</b>	1.38	3.1	2.29	3.34	<b>0.63</b>	1.41	1.04	1.52
Columbus	2.15	<b>0.81</b>	2.05	2.34	1.74	2.72	<b>0.95</b>	1.09	<b>0.81</b>	1.26
Dallas	1.41	<b>0.94</b>	1.2	1.49	1.51	1.61	<b>0.85</b>	1.06	1.07	1.15
Denver	1.58	<b>0.93</b>	1.68	1.8	1.39	1.55	1.06	1.14	<b>0.88</b>	<b>0.98</b>
Detroit	1.67	<b>0.88</b>	1.16	2.29	1.52	1.56	<b>0.69</b>	1.37	<b>0.91</b>	<b>0.93</b>
Hartford	2.43	<b>0.83</b>	<b>0.99</b>	4.11	4.09	1.89	<b>0.41</b>	1.70	1.69	<b>0.78</b>
Houston	1.24	<b>0.95</b>	1.19	1.24	1.22	1.62	<b>0.96</b>	<b>1.00</b>	<b>0.98</b>	1.30
Indianapolis	2.12	<b>0.84</b>	1.77	2.88	2.00	2.56	<b>0.84</b>	1.36	<b>0.94</b>	1.21
Jacksonville	1.78	<b>0.88</b>	1.29	2.62	1.57	1.96	<b>0.72</b>	1.47	<b>0.88</b>	1.10
Kansas City	1.81	<b>0.9</b>	1.26	2.88	2.33	2.15	<b>0.69</b>	1.59	1.28	1.19
Las Vegas	1.51	<b>0.91</b>	1.25	1.63	1.75	1.44	<b>0.82</b>	1.08	1.16	<b>0.95</b>
Los Angeles	1.43	<b>0.92</b>	1.26	1.32	1.46	1.66	<b>0.88</b>	<b>0.92</b>	1.01	1.16
Louisville	2.09	<b>0.84</b>	1.48	3.91	1.35	2.16	<b>0.71</b>	1.87	<b>0.64</b>	1.03
Miami	1.37	<b>0.93</b>	1.01	1.23	1.66	1.04	<b>0.73</b>	<b>0.90</b>	1.21	<b>0.76</b>
Milwaukee	1.92	<b>0.86</b>	1.49	2.02	2.80	2.06	<b>0.78</b>	1.05	1.46	1.07
Minneapolis	2.49	<b>0.84</b>	1.96	4.05	2.99	2.85	<b>0.79</b>	1.63	1.20	1.14
Nashville	1.79	<b>0.82</b>	1.35	3.04	1.16	2.22	<b>0.75</b>	1.70	<b>0.65</b>	1.24
New Orleans	1.42	<b>0.91</b>	1.21	1.57	1.51	1.28	<b>0.85</b>	1.11	1.07	<b>0.9</b>
New York	1.3	<b>0.95</b>	1.33	1.22	1.18	1.71	1.03	<b>0.94</b>	<b>0.91</b>	1.32
Oklahoma City	1.63	<b>0.9</b>	1.31	2.13	2.20	1.67	<b>0.80</b>	1.30	1.35	1.02
Orlando	1.31	<b>0.95</b>	1.14	2.17	1.03	1.13	<b>0.87</b>	1.65	<b>0.79</b>	<b>0.86</b>
Philadelphia	2.20	<b>0.83</b>	1.37	2.89	2.55	2.76	<b>0.62</b>	1.31	1.16	1.25

Phoenix	1.60	<b>0.90</b>	1.34	1.93	1.79	1.63	<b>0.84</b>	1.21	1.12	1.02
Pittsburgh	2.18	<b>0.83</b>	1.74	3.33	3.33	4.43	<b>0.80</b>	1.53	1.53	2.03
Portland	1.41	<b>0.94</b>	1.42	2.02	1.07	1.55	1.01	1.43	<b>0.76</b>	1.10
Providence	1.81	<b>0.88</b>	1.22	2.86	2.91	2.45	<b>0.68</b>	1.59	1.61	1.36
Raleigh	1.79	<b>0.88</b>	1.58	2.25	1.69	1.86	<b>0.88</b>	1.25	<b>0.94</b>	1.04
Richmond	2.32	<b>0.84</b>	2.19	2.43	1.48	3.48	<b>0.95</b>	1.05	<b>0.64</b>	1.50
Riverside	1.32	<b>0.94</b>	<b>0.98</b>	1.49	1.44	1.55	<b>0.74</b>	1.13	1.09	1.17
Sacramento	1.49	<b>0.92</b>	1.41	1.89	1.54	1.42	<b>0.94</b>	1.27	1.04	<b>0.96</b>
Saint Louis	1.76	<b>0.90</b>	1.24	2.53	1.58	2.70	<b>0.70</b>	1.44	<b>0.90</b>	1.53
Salt Lake City	1.57	<b>0.94</b>	1.55	2.21	1.42	1.88	<b>0.99</b>	1.41	<b>0.91</b>	1.20
San Antonio	1.60	<b>0.90</b>	1.17	1.69	1.75	1.65	<b>0.73</b>	1.05	1.09	1.03
San Diego	1.42	<b>0.94</b>	1.28	1.72	1.51	1.39	<b>0.9</b>	1.22	1.07	<b>0.99</b>
San Francisco	1.45	<b>0.95</b>	1.58	1.40	1.01	1.75	1.09	<b>0.97</b>	<b>0.70</b>	1.21
San Jose	1.26	<b>0.97</b>	1.29	1.53	1.28	1.19	1.02	1.21	1.02	<b>0.95</b>
Seattle	1.49	<b>0.94</b>	1.44	1.62	1.02	1.89	<b>0.96</b>	1.09	<b>0.68</b>	1.26
Tampa	1.42	<b>0.92</b>	1.08	2.50	1.44	1.31	<b>0.76</b>	1.77	1.01	<b>0.93</b>
Virginia Beach	1.57	<b>0.91</b>	1.15	2.01	1.37	1.45	<b>0.73</b>	1.28	<b>0.87</b>	<b>0.93</b>
Washington DC	1.55	<b>0.95</b>	1.83	1.45	1.22	1.48	1.18	<b>0.94</b>	<b>0.78</b>	<b>0.95</b>
Average Ratio	1.73	0.89	1.42	2.24	1.75	2.08	0.83	1.28	1.00	1.18
Median Ratio	1.60	0.90	1.33	2.08	1.54	1.86	0.82	1.27	0.94	1.15
Stand. Deviation	0.35	0.05	0.35	0.77	0.66	0.78	0.16	0.26	0.26	0.28
Minimum Ratio	1.24	0.78	0.98	1.22	1.01	1.04	0.41	0.81	0.64	0.76
Maximum Ratio	2.49	0.97	2.93	4.11	4.09	4.7	1.21	1.87	1.69	2.03

**Table 2.** Sufficiency analysis: Number of people and share of population affected by insufficient accessibility across all 49 metropolitan areas.

<b>Sufficiency threshold</b>	<b>1%</b>	<b>10%</b>	<b>20%</b>	<b>30%</b>	<b>40%</b>	<b>50%</b>
Number of people affected	10,883,653	19,684,987	20,831,732	21,264,857	21,487,845	21,659,188
Share of total population	6.4%	11.6%	12.2%	12.5%	12.6%	12.7%
Share of total poor population	49.8%	90.1%	95.3%	97.3%	98.3%	99.1%

**Table 3.** Disparity-in-insufficiency analysis: (a) The relative share of each racial group in the total poor population experiencing insufficient accessibility; and (b) the relative contribution of each racial group to overall accessibility insufficiency (ASI contribution ratios). Ratio values above 1 imply that a group carries more than its fair share and so is relatively disadvantaged.

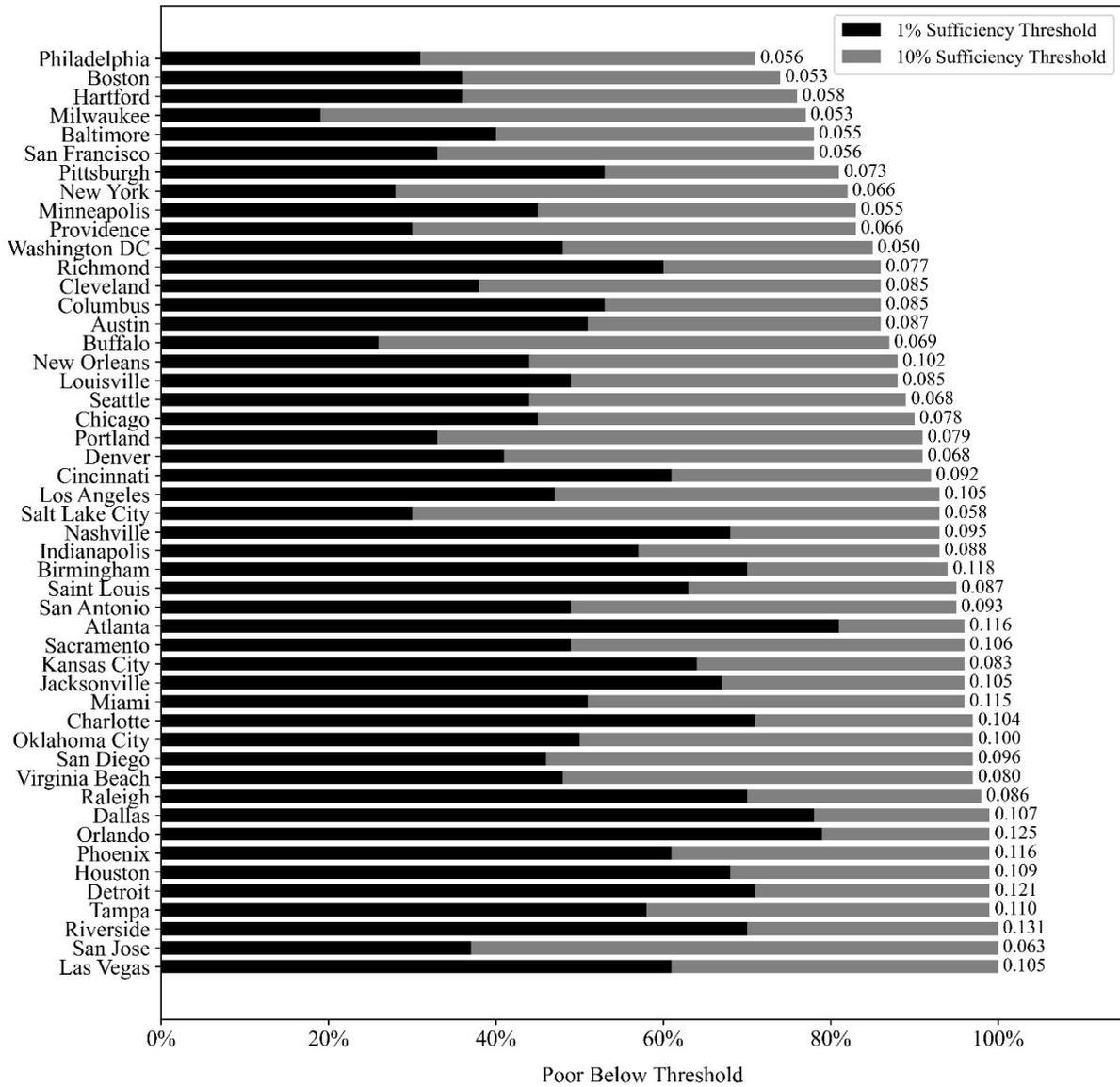
	<b>(a) Ratio based on poor population</b>						<b>(b) Ratio based on a Group's Contribution to Accessibility Insufficiency</b>					
	1%	10%	20%	30%	40%	50%	1%	10%	20%	30%	40%	50%
White	1.21	1.01	1.00	1.00	1.00	1.00	1.47	1.13	1.08	1.06	1.05	1.04
Black	0.83	0.96	0.99	1.00	1.00	1.00	0.60	0.90	0.94	0.96	0.98	0.98
Hispanic	0.89	1.02	1.02	1.01	1.01	1.00	0.69	0.91	0.94	0.95	0.95	0.96
Other	0.85	0.96	0.97	0.97	0.98	0.99	0.85	0.95	0.97	0.98	0.98	0.99

**Table 4.** Disparity-in-insufficiency analysis: Ratios representing the relative share of accessibility insufficiency carried by each racial group in relation to a benchmark population, for the 10%-sufficiency threshold (ASI contribution ratios). Ratios above 1 (highlighted in bold) indicate that a group carries more than its fair share of accessibility insufficiency.

Metropolitan Area	By Income and Race							
	Relative to Total Population				Relative to Poor Population			
	<i>White</i>	<i>Black</i>	<i>Hispanic</i>	<i>Other</i>	<i>White</i>	<i>Black</i>	<i>Hispanic</i>	<i>Other</i>
Atlanta	<b>1.01</b>	0.99	<b>1.02</b>	0.97	<b>1.03</b>	0.98	1.00	0.94
Austin	0.94	<b>1.05</b>	<b>1.08</b>	0.80	0.98	<b>1.04</b>	<b>1.05</b>	0.78
Baltimore	<b>1.15</b>	0.85	<b>1.04</b>	<b>1.05</b>	<b>1.30</b>	0.70	<b>1.07</b>	<b>1.13</b>
Birmingham	<b>1.02</b>	0.97	<b>1.02</b>	0.95	<b>1.10</b>	0.88	<b>1.01</b>	0.93
Boston	<b>1.05</b>	1.00	0.95	0.85	<b>1.15</b>	0.78	0.84	0.74
Buffalo	<b>1.08</b>	0.89	0.80	0.99	<b>1.23</b>	0.67	0.57	0.80
Charlotte	<b>1.01</b>	0.98	<b>1.03</b>	<b>1.01</b>	<b>1.08</b>	0.91	0.99	0.96
Chicago	1.00	<b>1.00</b>	<b>1.04</b>	0.89	<b>1.11</b>	0.94	0.96	0.83
Cincinnati	<b>1.03</b>	0.91	<b>1.03</b>	0.94	<b>1.08</b>	0.79	0.99	0.91
Cleveland	<b>1.08</b>	0.92	0.99	0.89	<b>1.18</b>	0.80	0.94	0.86
Columbus	1.00	0.99	<b>1.06</b>	0.96	<b>1.05</b>	0.90	<b>1.05</b>	0.87
Dallas	1.00	1.00	1.00	1.00	<b>1.03</b>	0.99	0.98	0.98
Denver	0.98	0.99	<b>1.03</b>	<b>1.01</b>	<b>1.02</b>	0.90	1.00	0.99
Detroit	1.00	0.99	<b>1.01</b>	0.99	<b>1.06</b>	0.93	1.00	<b>1.02</b>
Hartford	<b>1.23</b>	0.73	0.73	<b>1.10</b>	<b>1.38</b>	0.53	0.57	<b>1.12</b>
Houston	0.98	1.00	<b>1.01</b>	0.99	<b>1.05</b>	0.99	0.98	0.95
Indianapolis	<b>1.02</b>	0.96	<b>1.02</b>	0.97	<b>1.07</b>	0.86	0.97	0.99
Jacksonville	<b>1.02</b>	0.98	<b>1.01</b>	0.98	<b>1.07</b>	0.88	<b>1.02</b>	0.99
Kansas City	<b>1.02</b>	0.95	<b>1.01</b>	0.99	<b>1.09</b>	0.84	0.88	0.95
Las Vegas	1.00	1.00	1.00	1.00	<b>1.05</b>	0.97	0.95	<b>1.02</b>
Los Angeles	<b>1.03</b>	<b>1.02</b>	1.00	0.96	<b>1.02</b>	<b>1.02</b>	0.99	0.99
Louisville	<b>1.05</b>	0.85	<b>1.10</b>	<b>1.01</b>	<b>1.12</b>	0.66	<b>1.06</b>	0.95
Miami	<b>1.03</b>	<b>1.02</b>	0.97	<b>1.02</b>	<b>1.08</b>	<b>1.01</b>	0.95	<b>1.07</b>
Milwaukee	<b>1.08</b>	1.00	0.80	0.93	<b>1.33</b>	0.83	0.49	0.94
Minneapolis	<b>1.05</b>	0.83	0.95	1.00	<b>1.16</b>	0.63	0.80	0.82
Nashville	<b>1.03</b>	0.92	<b>1.05</b>	0.99	<b>1.08</b>	0.81	<b>1.02</b>	0.97
New Orleans	<b>1.04</b>	0.96	<b>1.01</b>	<b>1.04</b>	<b>1.05</b>	0.97	0.93	<b>1.03</b>
New York	0.99	0.99	<b>1.03</b>	0.95	<b>1.20</b>	0.95	0.90	0.88
Oklahoma City	<b>1.01</b>	0.97	0.99	1.00	<b>1.07</b>	0.93	0.85	1.00
Orlando	1.00	0.98	<b>1.01</b>	<b>1.01</b>	<b>1.02</b>	0.93	<b>1.02</b>	<b>1.01</b>
Philadelphia	<b>1.21</b>	0.84	0.86	0.94	<b>1.45</b>	0.64	0.70	0.89
Phoenix	1.00	0.99	1.00	1.00	<b>1.04</b>	0.95	0.97	0.99
Pittsburgh	<b>1.06</b>	0.83	0.86	0.77	<b>1.11</b>	0.60	0.81	0.71

Portland	0.99	0.95	<b>1.06</b>	1.00	<b>1.02</b>	0.79	<b>1.01</b>	0.93
Providence	<b>1.10</b>	0.82	0.80	0.89	<b>1.25</b>	0.57	0.51	0.75
Raleigh	1.00	<b>1.01</b>	<b>1.01</b>	0.99	<b>1.03</b>	0.94	1.00	0.98
Richmond	1.00	1.00	<b>1.08</b>	0.91	<b>1.08</b>	0.91	<b>1.12</b>	0.90
Riverside	1.00	1.00	1.00	1.00	<b>1.05</b>	0.98	0.98	0.97
Sacramento	1.00	0.98	1.00	<b>1.01</b>	<b>1.03</b>	0.91	0.97	<b>1.01</b>
Saint Louis	<b>1.02</b>	0.97	<b>1.03</b>	0.96	<b>1.10</b>	0.86	1.00	0.86
Salt Lake City	0.99	0.96	<b>1.04</b>	0.98	<b>1.03</b>	0.73	<b>1.01</b>	0.87
San Antonio	<b>1.01</b>	0.99	1.00	0.98	<b>1.13</b>	0.98	0.95	<b>1.02</b>
San Diego	0.99	0.98	<b>1.01</b>	<b>1.01</b>	<b>1.06</b>	0.93	0.96	0.99
San Francisco	0.96	0.97	<b>1.11</b>	0.95	1.00	0.94	<b>1.14</b>	0.88
San Jose	1.00	1.00	1.00	1.00	0.99	0.91	0.99	<b>1.02</b>
Seattle	1.00	<b>1.01</b>	1.06	0.96	<b>1.03</b>	0.93	<b>1.06</b>	0.91
Tampa	<b>1.01</b>	0.97	1.00	<b>1.01</b>	<b>1.06</b>	0.81	0.99	1.00
Virginia Beach	<b>1.02</b>	0.98	<b>1.01</b>	<b>1.01</b>	<b>1.09</b>	0.91	<b>1.03</b>	<b>1.01</b>
Washington DC	0.96	<b>1.01</b>	<b>1.06</b>	<b>1.02</b>	<b>1.03</b>	0.94	<b>1.03</b>	<b>1.04</b>
Average Ratio	0.85	1.31	1.26	0.93	1.10	0.86	0.94	0.94
Median Ratio	0.86	1.30	1.28	0.93	1.07	0.91	0.99	0.96
Standard Deviation	0.08	0.18	0.17	0.13	0.10	0.13	0.14	0.09
Minimum Ratio	0.69	0.89	0.81	0.71	0.98	0.53	0.49	0.71
Maximum Ratio	1.01	1.76	1.62	1.36	1.45	1.04	1.14	1.13

**Figure 1.** Sufficiency analysis: Share of the poor population in each region facing insufficient accessibility when employing the 1%- and 10%-sufficiency threshold. The number behind each bar represents the regional Accessibility Sufficiency Index (ASI) score for the 10%-sufficiency threshold; the higher the number the more inequitable the region.



## Technical Appendix

### The Accessibility Sufficiency Index

Formally, the Accessibility Sufficiency Index for a metropolitan area  $r$  ( $ASI_r$ ) is defined as follows:

$$ASI_r = \frac{1}{N} * \sum_{i=1}^q n_i * ((z - y_i)/z)^2 \quad (1)$$

where  $N$  represents the total population in region  $r$ ;  $q$  is the number of groups (e.g., income groups or groups defined by race) in region  $r$  experiencing accessibility levels below the sufficiency threshold;  $n_i$  is the size of the  $i$ -th group in number of persons;  $z$  is the accessibility sufficiency threshold as defined for a metropolitan area  $r$ ; and  $y_i$  is the accessibility level below the accessibility sufficiency threshold  $z$  experienced by the  $i$ -th group. In case data are available or collected for each individual, the ASI can be calculated based on the situation of each person, i.e. for the case that  $n = 1$ . If no such data are available or can be collected in light of privacy considerations or other constraints, the ASI can also be calculated based on the accessibility level enjoyed by (small) groups (e.g., all low-income persons in a BG or low-income). As long as the distinguished groups are relatively homogeneous in both residential location and the transport modes available to them and thus in their accessibility level, such an analysis still accounts in a meaningful way for the situation of each person.

As mentioned in the main text, two dimensions of insufficient accessibility affect the regional ASI score: First, the more people experiencing insufficient accessibility, the higher the ASI score. Second, the lower the level of accessibility experienced by people below the sufficiency threshold, the higher the ASI score.

The ASI also allows calculating the contribution of each person or population group to overall accessibility insufficiency in a region as a percentage, with the contributions of all persons or subgroups together adding up to exactly 100%. The ASI contribution of a given group  $i$  can be calculated as:

$$ASICON_i = \left(\frac{n_i}{N}\right) * \left(\frac{((z - y_i)/z)^2}{ASI_r}\right) \quad (2)$$

The ASICON can be calculated for individuals ( $n = 1$ ) as well as for groups of different sizes, ranging from relatively small and homogenous groups (a racial group in a census block) up to large and heterogenous groups (e.g., a racial group in a metropolitan area; all residents in a particular suburb within a region; and so on). Even in the latter case, each person affected by insufficient accessibility is still accounted for in the calculation of the group's ASI contribution. Both the ASI and the ASICON thus are in line with the philosophical requirement that the ultimate units of concern are persons.

### Data Preparation

The analyses carried out in the paper require demographic information on block group population, poverty status, and race and ethnicity. In order to obtain these data, we combined several tables from the American Community Survey 2011-2015 5-year estimates. Total population data were extracted from the 'X01 AGE AND SEX' table. Race data were retrieved from the 'X03 HISPANIC OR LATINO ORIGIN' table, as it enables better differentiation between racial groups than the 0X02 Race0 table. Poverty

status was obtained by calculating the poor rate from the 'X21 VETERAN STATUS' table. While the 'X17 Poverty' table provides data on households, the veteran status table offers data on adults (+18) sorted by 'AGE BY VETERAN STATUS BY POVERTY STATUS' and also includes data on race. In the absence of detailed data on the share of poor among each racial group in each block group, the following data manipulations were applied as proxies. Assuming that the poor rate among the entire population in a block group is the same as among adults in that block group, we obtained the total poor population in each block group by multiplying the 'Total Population' field (from the 'X01 AGE AND SEX' table) by poor adult rate (from the 'AGE BY VETERAN STATUS BY POVERTY STATUS' field). Similarly, we calculated the number of poor for each racial group (e.g., 'White Alone' multiply by 'Poor Rate' for Whites only).

## Appendices

### Appendix A. Sufficiency analysis

**Table A1.** Sufficiency analysis: Number of poor people with transit accessibility below the 10%-sufficiency threshold, by race.

Metropolitan Area	Total Population	Total Poor Population	Poor Population Below Sufficiency Threshold <sup>1</sup>		Poor Population Below Sufficiency Threshold by Race <sup>2</sup>			
			Total	Share among Poor Population	White	Black	Hispanic	Other
Atlanta	5,517,937	745,347	712,800	96%	268,502	298,751	98,157	47,390
Austin	1,889,094	250,469	214,924	86%	86,585	19,778	96,337	12,224
Baltimore	2,769,818	281,586	217,996	77%	102,921	86,424	12,846	15,804
Birmingham	1,138,476	167,727	157,483	94%	80,494	65,421	7,995	3,574
Boston	4,694,565	470,848	348,112	74%	207,944	42,878	59,737	37,553
Buffalo	1,135,734	154,506	133,779	87%	83,587	29,868	8,711	11,613
Charlotte	1,868,103	240,808	231,880	96%	108,585	76,191	32,777	14,326
Chicago	9,534,008	1,180,162	1,057,483	90%	373,895	328,110	291,664	63,814
Cincinnati	2,155,102	270,482	246,340	91%	173,038	53,257	9,841	10,205
Cleveland	2,064,483	283,720	243,834	86%	129,425	84,628	19,772	10,009
Columbus	1,907,436	245,414	208,747	85%	131,079	51,051	11,748	14,869
Dallas	6,776,864	853,298	838,738	98%	282,754	173,041	327,419	55,525
Denver	2,703,972	279,118	253,715	91%	127,187	19,533	88,918	18,077
Detroit	4,296,416	636,978	628,865	99%	296,513	259,846	36,824	35,682
Hartford	1,214,056	128,336	96,852	75%	58,255	12,142	19,032	7,423
Houston	6,373,676	857,436	840,309	98%	207,169	177,897	399,206	56,037
Indianapolis	1,820,394	224,180	207,135	92%	123,710	51,094	22,912	9,420
Jacksonville	1,401,600	189,819	181,315	96%	98,737	57,860	14,198	10,520
Kansas City	2,081,428	227,626	216,331	95%	128,787	45,846	29,157	12,541
Las Vegas	2,035,572	282,347	281,044	100%	102,978	36,494	108,953	32,619
Los Angeles	13,149,660	2,004,153	1,862,897	93%	403,368	155,965	1,026,561	277,004
Louisville	1,311,815	170,236	149,136	88%	102,673	30,572	8,718	7,173
Miami	5,861,000	924,905	882,478	95%	211,675	244,246	398,579	27,978
Milwaukee	1,570,006	211,919	161,239	76%	76,299	53,778	21,406	9,756
Minneapolis	3,390,253	322,851	265,736	82%	173,432	34,179	22,111	36,014
Nashville	1,677,759	206,929	192,289	93%	120,687	43,500	18,627	9,474
New Orleans	1,218,047	200,892	175,395	87%	68,791	83,294	15,118	8,191

New York	19,307,638	2,546,821	2,073,195	81%	615,818	472,881	740,370	244,126
Oklahoma City	1,318,408	182,667	177,016	97%	99,274	24,117	32,381	21,244
Orlando	2,277,816	328,013	323,311	99%	139,025	63,831	99,670	20,784
Philadelphia	6,035,680	739,614	518,804	70%	256,329	155,896	67,143	39,436
Phoenix	4,407,915	658,741	646,516	98%	272,136	37,995	284,591	51,794
Pittsburgh	2,358,926	265,669	214,719	81%	173,254	28,790	3,275	9,399
Portland	2,320,323	293,425	266,736	91%	182,763	10,561	43,480	29,933
Providence	1,606,424	205,927	170,073	83%	118,144	10,715	28,778	12,435
Raleigh	1,216,711	131,089	128,178	98%	66,640	34,384	19,059	8,094
Richmond	1,297,166	144,096	123,265	86%	54,095	53,850	9,244	6,076
Riverside	4,392,801	696,064	696,064	100%	198,314	54,253	391,945	51,553
Sacramento	2,221,525	327,867	313,324	96%	142,523	28,307	80,841	61,653
Saint Louis	2,826,962	330,455	311,724	94%	183,963	103,474	10,653	13,634
Salt Lake City	1,178,372	123,609	114,175	92%	71,899	2,424	28,808	11,044
San Antonio	2,286,702	315,074	298,782	95%	71,953	21,332	196,029	9,469
San Diego	3,223,096	439,053	425,463	97%	166,194	23,761	176,692	58,815
San Francisco	4,528,894	489,062	380,565	78%	117,166	42,345	117,887	103,168
San Jose	1,925,706	180,923	180,751	100%	49,129	5,280	65,732	60,611
Seattle	3,614,361	383,651	339,485	88%	198,922	28,434	45,453	66,676
Tampa	2,888,458	407,261	399,892	98%	228,410	68,375	82,868	20,239
Virginia Beach	1,701,977	189,242	183,110	97%	78,728	80,042	12,039	12,301
Washington DC	5,893,548	463,020	392,990	85%	137,188	137,999	73,553	44,250
<b>Total</b>	<b>170,386,683</b>	<b>21,853,435</b>	<b>19,684,987</b>		<b>7,950,938</b>	<b>4,104,688</b>	<b>5,817,813</b>	<b>1,811,548</b>
Average	3,477,279	445,988	401,734	90%	162,264	83,769	118,731	36,970
Median	2,277,816	282,347	253,715	92%	129,425	51,094	36,824	18,077
Stan. Deviation	3,292,363	453,990	398,230	8%	104,615	94,711	195,469	51,620
Minimum	1,135,734	123,609	96,852	70%	49,129	2,424	3,275	3,574
Maximum	19,307,638	2,546,821	2,073,195	100%	615,818	472,881	1,026,561	277,004

<sup>1</sup> Poor population living in Block Groups with a transit accessibility level below the 10%-sufficiency threshold.

<sup>2</sup> As above, but distinguished by race.

## Appendix B. Disparity-in-insufficiency analysis

**Table B1.** Disparity-in-insufficiency analysis: Ratios representing the relative share of accessibility insufficiency carried by each racial group, for three distinct sufficiency thresholds (ASI contribution ratios). Ratios above 1 (highlighted in bold) indicate that a group carries more than its fair share of accessibility insufficiency.

Metropolitan Area	1% Sufficiency Threshold <sup>1</sup>				30% Sufficiency Threshold <sup>1</sup>				50% Sufficiency Threshold <sup>1</sup>			
	White	Black	Hispanic	Other	White	Black	Hispanic	Other	White	Black	Hispanic	Other
Atlanta	<b>1.21</b>	0.91	0.81	0.81	<b>1.01</b>	0.99	<b>1.01</b>	0.96	<b>1.01</b>	0.99	<b>1.01</b>	0.97
Austin	<b>1.09</b>	0.94	0.97	0.70	0.96	<b>1.04</b>	<b>1.07</b>	0.81	0.97	<b>1.03</b>	<b>1.05</b>	0.85
Baltimore	<b>1.70</b>	0.40	0.79	<b>1.05</b>	<b>1.16</b>	0.84	<b>1.05</b>	<b>1.07</b>	<b>1.10</b>	0.90	<b>1.04</b>	<b>1.04</b>
Birmingham	<b>1.44</b>	0.49	0.97	0.84	<b>1.04</b>	0.95	<b>1.01</b>	0.96	<b>1.03</b>	0.97	<b>1.01</b>	0.97
Boston	<b>1.52</b>	0.25	0.23	0.50	<b>1.08</b>	0.93	0.93	0.83	<b>1.05</b>	0.96	0.96	0.86
Buffalo	<b>1.54</b>	0.08	0.30	0.71	<b>1.09</b>	0.88	0.81	0.94	<b>1.05</b>	0.93	0.88	0.96
Charlotte	<b>1.32</b>	0.71	0.70	0.82	<b>1.03</b>	0.96	<b>1.01</b>	0.99	<b>1.02</b>	0.98	<b>1.01</b>	0.99
Chicago	<b>1.58</b>	0.66	0.68	0.81	<b>1.03</b>	0.98	<b>1.02</b>	0.87	<b>1.01</b>	0.99	<b>1.02</b>	0.89
Cincinnati	<b>1.29</b>	0.26	0.77	0.70	<b>1.04</b>	0.90	<b>1.01</b>	0.95	<b>1.02</b>	0.94	<b>1.01</b>	0.97
Cleveland	<b>1.65</b>	0.21	0.85	0.77	<b>1.09</b>	0.90	0.98	0.90	<b>1.05</b>	0.94	0.99	0.93
Columbus	<b>1.26</b>	0.51	0.73	0.67	<b>1.01</b>	0.97	<b>1.04</b>	0.94	<b>1.01</b>	0.99	<b>1.03</b>	0.96
Dallas	<b>1.22</b>	0.97	0.84	0.89	<b>1.01</b>	1.00	0.99	0.99	<b>1.01</b>	1.00	1.00	0.99
Denver	<b>1.36</b>	0.47	0.60	0.95	0.99	0.97	<b>1.02</b>	<b>1.00</b>	0.99	0.98	<b>1.01</b>	<b>1.00</b>
Detroit	<b>1.48</b>	0.48	0.81	<b>1.06</b>	<b>1.02</b>	0.97	<b>1.01</b>	<b>1.01</b>	1.01	0.98	<b>1.00</b>	<b>1.00</b>
Hartford	<b>1.71</b>	0.23	0.25	0.83	<b>1.20</b>	0.76	0.77	<b>1.07</b>	1.12	0.86	0.86	<b>1.05</b>
Houston	<b>1.42</b>	0.93	0.82	0.92	<b>1.01</b>	1.00	1.00	0.98	1.00	1.00	<b>1.00</b>	0.99
Indianapolis	<b>1.32</b>	0.46	0.62	0.89	<b>1.03</b>	0.94	<b>1.00</b>	0.98	1.02	0.96	<b>1.00</b>	0.98
Jacksonville	<b>1.25</b>	0.60	0.93	0.99	<b>1.03</b>	0.95	<b>1.01</b>	0.99	<b>1.02</b>	0.97	<b>1.01</b>	1.00
Kansas City	<b>1.28</b>	0.54	0.59	0.85	<b>1.04</b>	0.93	0.96	0.98	<b>1.02</b>	0.96	0.98	0.99
Las Vegas	<b>1.34</b>	0.80	0.67	<b>1.26</b>	<b>1.02</b>	0.99	0.98	<b>1.01</b>	<b>1.01</b>	1.00	0.99	<b>1.00</b>
Los Angeles	<b>1.55</b>	0.82	0.80	<b>1.06</b>	<b>1.02</b>	<b>1.01</b>	1.00	0.98	<b>1.01</b>	<b>1.01</b>	1.00	0.99
Louisville	<b>1.32</b>	0.25	0.76	0.65	<b>1.07</b>	0.81	<b>1.07</b>	0.99	<b>1.04</b>	0.88	<b>1.05</b>	1.00
Miami	<b>1.41</b>	0.80	0.89	<b>1.28</b>	<b>1.03</b>	<b>1.01</b>	0.97	<b>1.03</b>	<b>1.02</b>	<b>1.01</b>	0.98	<b>1.02</b>
Milwaukee	<b>2.05</b>	0.08	0.22	0.65	<b>1.11</b>	0.97	0.79	0.97	<b>1.06</b>	0.98	0.88	0.98
Minneapolis	<b>1.35</b>	0.28	0.50	0.52	<b>1.07</b>	0.81	0.92	0.94	<b>1.04</b>	0.88	0.96	0.97
Nashville	<b>1.25</b>	0.55	0.65	0.80	<b>1.04</b>	0.90	<b>1.04</b>	0.98	<b>1.02</b>	0.94	<b>1.03</b>	0.98
New Orleans	<b>1.29</b>	0.85	0.58	0.97	<b>1.03</b>	0.98	0.98	<b>1.02</b>	<b>1.02</b>	0.98	0.99	<b>1.02</b>
New York Oklahoma City	<b>2.11</b>	0.46	0.52	0.66	<b>1.04</b>	0.99	1.00	0.93	<b>1.01</b>	<b>1.01</b>	<b>1.01</b>	0.94
Orlando	<b>1.11</b>	0.72	<b>1.03</b>	<b>1.03</b>	<b>1.01</b>	0.97	<b>1.01</b>	<b>1.01</b>	<b>1.00</b>	0.98	<b>1.01</b>	<b>1.00</b>
Philadelphia	<b>1.75</b>	0.39	0.52	0.79	<b>1.24</b>	0.80	0.85	0.92	<b>1.16</b>	0.87	0.92	0.92
Phoenix	<b>1.26</b>	0.82	0.74	<b>1.16</b>	<b>1.02</b>	0.97	0.99	0.99	<b>1.01</b>	0.98	0.99	0.99
Pittsburgh	<b>1.21</b>	0.24	0.64	0.49	<b>1.07</b>	0.77	0.85	0.76	<b>1.05</b>	0.84	0.88	0.79
Portland	<b>1.20</b>	0.27	0.52	0.67	<b>1.00</b>	0.91	<b>1.04</b>	0.98	1.00	0.94	1.03	0.98
Providence	<b>1.46</b>	0.20	0.14	0.45	<b>1.11</b>	0.81	0.79	0.89	<b>1.06</b>	0.89	0.88	0.93
Raleigh	<b>1.10</b>	0.86	0.98	0.77	<b>1.01</b>	0.98	<b>1.00</b>	1.00	<b>1.01</b>	0.99	<b>1.00</b>	1.00
Richmond	<b>1.28</b>	0.77	0.88	0.78	<b>1.02</b>	0.98	<b>1.08</b>	0.91	<b>1.01</b>	0.99	<b>1.05</b>	0.93
Riverside	<b>1.35</b>	0.84	0.85	0.95	<b>1.02</b>	0.99	0.99	0.99	<b>1.01</b>	1.00	1.00	0.99
Sacramento	<b>1.29</b>	0.58	0.73	0.88	<b>1.01</b>	0.96	0.99	<b>1.01</b>	<b>1.01</b>	0.98	1.00	<b>1.00</b>

St Louis	<b>1.34</b>	0.49	0.84	0.69	<b>1.04</b>	0.94	<b>1.01</b>	0.93	<b>1.02</b>	0.96	<b>1.01</b>	0.96
Salt Lake City	<b>1.24</b>	0.39	0.63	0.53	<b>1.00</b>	0.90	<b>1.02</b>	0.95	<b>1.00</b>	0.94	<b>1.01</b>	0.97
San Antonio	<b>1.55</b>	0.73	0.83	<b>1.04</b>	<b>1.05</b>	0.99	0.98	1.00	<b>1.03</b>	1.00	0.99	1.00
San Diego	<b>1.36</b>	0.80	0.66	<b>1.06</b>	<b>1.02</b>	0.97	0.99	<b>1.00</b>	<b>1.01</b>	0.98	0.99	<b>1.00</b>
San Francisco	<b>1.35</b>	0.79	0.95	0.75	0.98	0.98	<b>1.11</b>	0.93	0.98	1.00	<b>1.08</b>	0.95
San Jose	<b>1.36</b>	0.64	0.95	0.80	1.00	0.97	1.00	<b>1.01</b>	1.00	0.98	1.00	<b>1.00</b>
Seattle	<b>1.24</b>	0.49	0.75	0.68	<b>1.01</b>	0.98	<b>1.06</b>	0.95	<b>1.01</b>	0.99	<b>1.05</b>	0.96
Tampa	<b>1.21</b>	0.45	0.93	0.90	<b>1.02</b>	0.93	1.00	<b>1.01</b>	<b>1.01</b>	0.96	1.00	<b>1.00</b>
Virginia Beach	<b>1.41</b>	0.63	0.91	0.96	<b>1.03</b>	0.97	<b>1.01</b>	<b>1.01</b>	<b>1.02</b>	0.98	<b>1.01</b>	<b>1.01</b>
Washington DC	<b>1.40</b>	0.72	0.73	1.00	0.98	0.99	<b>1.05</b>	<b>1.02</b>	0.98	1.00	<b>1.04</b>	<b>1.02</b>
Average	1.39	0.56	0.70	0.84	1.04	0.94	0.98	0.97	1.02	0.96	0.99	0.97
Median	1.34	0.55	0.74	0.82	1.03	0.97	1.00	0.98	1.01	0.98	1.00	0.99
Standard Deviation	0.21	0.25	0.22	0.19	0.05	0.07	0.07	0.06	0.03	0.04	0.05	0.05
Minimum	1.09	0.08	0.14	0.45	0.96	0.76	0.77	0.76	0.97	0.84	0.86	0.79
Maximum	2.11	0.97	1.03	1.28	1.24	1.04	1.11	1.07	1.16	1.03	1.08	1.05

<sup>1</sup> The thresholds are based on the number of jobs the average person in a region with a car can reach within 30-minutes travel time during rush hour. If the average person can reach 1 million jobs by car, the 1%-threshold would be equal to 10,000 jobs, the 30%-threshold to 300,000 jobs, and the 50%-threshold to 500,000 jobs.

**Table B2.** Disparity-in-insufficiency analysis employing the 10%-sufficiency threshold: Weighted average transit accessibility by racial group for the population below the sufficiency threshold only, expressed in (a) absolute number of jobs; and (b) as a percentage of the 10%-sufficiency threshold.

Metropolitan Area	10% Threshold <sup>1</sup>	(a) Weighted Average Transit Accessibility by Race <sup>2</sup>				(b) Weighted Average Transit Accessibility Expressed as % of Sufficiency Threshold, by Race			
		<i>White</i>	<i>Black</i>	<i>Hispanic</i>	<i>Other</i>	<i>White</i>	<i>Black</i>	<i>Hispanic</i>	<i>Other</i>
Atlanta	80,481	3,900	5,186	5,254	5,942	4.8	6.4	6.5	7.4
Austin	60,075	7,845	9,268	9,700	9,925	13.1	15.4	16.1	16.5
Baltimore	79,521	10,284	22,617	13,668	12,591	12.9	28.4	17.2	15.8
Birmingham	29,848	1,405	4,224	2,998	2,936	4.7	14.2	10.0	9.8
Boston	93,858	12,946	27,688	22,143	23,863	13.8	29.5	23.6	25.4
Buffalo	43,190	8,930	15,754	17,674	15,874	20.7	36.5	40.9	36.8
Charlotte	56,212	3,448	8,248	6,417	7,641	6.1	14.7	11.4	13.6
Chicago	127,762	16,902	27,106	26,951	27,988	13.2	21.2	21.1	21.9
Cincinnati	58,939	5,771	11,131	8,009	8,360	9.8	18.9	13.6	14.2
Cleveland	60,290	7,626	14,663	12,171	11,881	12.6	24.3	20.2	19.7
Columbus	64,744	7,359	11,951	8,769	12,463	11.4	18.5	13.5	19.2
Dallas	134,625	8,721	11,281	12,778	12,182	6.5	8.4	9.5	9.0
Denver	99,203	14,362	19,723	17,471	16,633	14.5	19.9	17.6	16.8
Detroit	98,849	6,971	13,740	9,574	8,474	7.1	13.9	9.7	8.6
Hartford	58,864	6,361	19,752	17,292	9,089	10.8	33.6	29.4	15.4
Houston	115,018	8,666	12,671	13,283	15,381	7.5	11.0	11.5	13.4
Indianapolis	61,924	7,121	12,121	10,347	7,637	11.5	19.6	16.7	12.3
Jacksonville	39,431	3,421	6,563	4,287	4,330	8.7	16.6	10.9	11.0
Kansas City	60,868	5,235	11,842	11,715	8,891	8.6	19.5	19.2	14.6
Las Vegas	76,840	9,306	12,289	13,167	10,654	12.1	16.0	17.1	13.9
Los Angeles	232,310	39,039	35,393	36,633	34,792	16.8	15.2	15.8	15.0
Louisville	44,398	5,757	12,811	7,729	8,531	13.0	28.9	17.4	19.2
Miami	99,189	11,901	14,255	15,977	12,069	12.0	14.4	16.1	12.2
Milwaukee	63,666	15,430	24,672	33,933	21,034	24.2	38.8	53.3	33.0
Minneapolis	102,385	15,467	34,038	29,424	29,896	15.1	33.2	28.7	29.2
Nashville	37,963	2,872	6,484	4,119	4,190	7.6	17.1	10.8	11.0
New Orleans	31,766	6,064	5,908	7,313	6,233	19.1	18.6	23.0	19.6
New York	263,058	39,750	69,147	78,244	70,781	15.1	26.3	29.7	26.9
Oklahoma City	41,386	5,250	7,386	9,273	6,529	12.7	17.8	22.4	15.8
Orlando	70,038	4,258	6,895	4,200	4,374	6.1	9.8	6.0	6.2

Philadelphia	99,236	12,818	34,392	32,697	25,277	12.9	34.7	32.9	25.5
Phoenix	100,610	10,423	14,424	13,890	13,127	10.4	14.3	13.8	13.0
Pittsburgh	42,562	3,966	12,489	6,484	6,909	9.3	29.3	15.2	16.2
Portland	68,722	12,291	19,281	14,104	15,593	17.9	28.1	20.5	22.7
Providence	41,065	7,721	16,617	17,633	13,313	18.8	40.5	42.9	32.4
Raleigh	56,696	5,514	9,074	6,534	6,732	9.7	16.0	11.5	11.9
Richmond	41,326	3,201	7,178	3,884	5,172	7.7	17.4	9.4	12.5
Riverside	58,302	4,207	6,429	6,209	6,666	7.2	11.0	10.7	11.4
Sacramento	60,613	7,925	11,661	10,123	8,882	13.1	19.2	16.7	14.7
Saint Louis	65,344	5,818	12,683	9,360	12,067	8.9	19.4	14.3	18.5
Salt Lake City	64,581	16,284	24,675	17,409	20,506	25.2	38.2	27.0	31.8
San Antonio	61,430	8,177	12,401	13,191	10,597	13.3	20.2	21.5	17.3
San Diego	80,903	10,839	15,155	15,515	14,023	13.4	18.7	19.2	17.3
San Francisco	113,488	22,792	25,148	21,962	29,082	20.1	22.2	19.4	25.6
San Jose	106,096	22,159	26,238	22,038	20,505	20.9	24.7	20.8	19.3
Seattle	74,469	12,334	15,420	12,649	15,352	16.6	20.7	17.0	20.6
Tampa	62,383	6,091	13,147	7,915	7,719	9.8	21.1	12.7	12.4
Virginia Beach	38,161	4,568	7,074	5,513	5,848	12.0	18.5	14.4	15.3
Washington DC	115,742	15,649	23,106	19,191	17,432	13.5	20.0	16.6	15.1
Average	78,335	10,105	16,355	14,833	13,999	12.5	21.2	18.7	17.5
Median	64,581	7,845	12,811	12,649	11,881	12.6	19.4	16.7	15.8
Stan. Deviation	44,125	7,787	11,081	12,286	11,139	4.8	8.2	9.3	7.0
Minimum	29,848	1,405	4,224	2,998	2,936	4.7	6.4	6.0	6.2
Maximum	263,058	39,750	69,147	78,244	70,781	25.2	40.5	53.3	36.8

<sup>1</sup> Figures represent number of jobs. The 10%-threshold is based on the number of jobs the average person in a region with a car can reach within 30-minutes travel time during rush hour. If the average person can reach 1 million jobs by car, the 10%-threshold would be equal to 100,000 jobs.

<sup>2</sup> The average number of jobs a poor person can reach by transit within 30-minutes door-to-door travel time during rush hour.